NASA TECH BRIEF

Lewis Research Center

Oxidation Resistant, Thoria-Dispersed Nickel-Chromium-Aluminum Alloy

A modified thoria-dispersed nickel-chromium (ThO_2-dispersed NiCr) alloy has been developed that exhibits greatly improved resistance to high temperature oxidation. Additions of aluminum have been made to change the nature of the protective oxide scale entirely and essentially inhibit oxidation at temperatures up to 1260° C (2300° F) under the most drastic test environments.

When ThO_2-dispersed NiCr (Ni-20Cr-2ThO_2) is exposed to air at elevated temperatures, the material oxidizes forming a protective Cr_2O_3 oxide scale, but the Cr_2O_3 can oxidize to CrO_3, a volatile compound. The rate of formation and evaporation of CrO_3 and, subsequently, loss of chromium from the alloy, is chiefly a function of temperature, gas velocity, angle of impingement, stress, and total dynamic pressure. Since it is possible that standard ThO_2-dispersed NiCr may not survive in a severe oxidation environment (particularly those found in aerospace applications), modifications of the basic composition are desired to reduce the loss of chromium from the alloy without impairing other requisite properties.

One approach to the problem has been to utilize aluminum in the nickel-chromium alloy matrix. In this manner, Cr_2O_3 formation is greatly suppressed in favor of the non volatile Al_2O_3 and $NiAl_2O_4$ species. Al_2O_3 becomes the principal protective oxide and the oxidation behavior is improved dramatically. Evaluation of sheet material showed that aluminum modified ThO_2-dispersed NiCr alloys have excellent oxidation resistance at 1200° C (2200° F) under cyclic, high gas flow conditions at pressures as low as 10 Torr.

Additional studies have shown that the aluminum content may be quite critical. The lower limit for the aluminum content appears to be in the 2.8 to 3.5% range and is determined by a loss in oxidation performance. An upper limit for the aluminum content in sheet application would appear to be dictated by the appearance of the gamma prime phase in the microstructure at an aluminum content in the range of 4.5 to 5.5%. The gamma prime phase, although adding to high temperature strength, detracts from formability behavior both for the manufacture of sheet and for the subsequent forming of hardware. One of the better Al-modified alloys is Ni-16Cr-3.5Al-2ThO_2.

Notes:

1. This modified alloy system permits the use of the ThO_2-dispersed NiCr base alloy under severe oxidizing environments without the use of a coating.
2. Application of the ThO_2-dispersed NiCrAl alloy can be made up to within 140° C (250° F) (i.e., 1260° C) of its melting point of 1440° C (2550° F).
3. The following documentation may be obtained from:
   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $26.50
   (or microfiche $0.95)

   Reference: NASA CR-120796 (N73-11512), Final Report – Development of Dispersion Strengthened Nickel-Chromium Alloy (Ni-Cr-ThO_2) Sheet for Space Shuttle Vehicles
4. Technical questions may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B73-10077

Patent status:

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)] to Fansteel, Inc., Baltimore, Maryland 21226.

Source: Sanford Baranow and Leo J. Klingler of
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